

Client's ref.: 91242&92137/bottle-shaped trench  
Our ref: 0548-9826-US/final/ice, Steve

## TITLE

### METHOD FOR FORMING BOTTLE-SHAPED TRENCH

#### BACKGROUND OF THE INVENTION

##### Field of the Invention

5       The invention relates to a bottle-shaped trench fabrication method, and more particularly to a fabrication method for forming a bottle-shaped trench by plasma nitridation.

##### Description of the Related Art

10       Generally speaking, capacitors widely used in dynamic random access memory (DRAM) are formed by two conductive layers (electrode plates) having an insulation layer therebetween. The ability to store the electric charge of a capacitor depends on the thickness and electrical  
15 characteristics of the insulation layer, and the surface area of the electrode plate. Recent developments to reduce the size of semiconductor elements to enhance integration density require the memory cell area to be continuously reduced to hold a large number of memory cells, and thereby  
20 increase density. The electrode plates of a capacitor in a memory cell however must provide sufficient surface area to store sufficient electric charge.

      Nevertheless, when element size is continuously reduced, the trench storage node capacitance of DRAM is also  
25 reduced. As a result, storage capacitance must be increased to maintain excellent memory operating performance.

Currently, the method for increasing DRAM storage capacitance increases the width of the bottom of a trench, thereby increasing surface area by forming bottle-shaped trench capacitors.

5        FIGs. 1A to 1K are cross-sections showing the conventional method for forming a bottle-shaped trench. In FIG 1A, a substrate 100 with a trench therein is provided, a pad layer is formed on the substrate 100, and the pad layer comprises an oxide layer 102 and a nitride layer 104. A  
10        sidewall oxide layer 106 is formed on the trench sidewall by thermal oxidation. A protective nitride layer 108 and a polysilicon layer 110 are formed thereon by chemical vapor deposition (CVD). In FIG 1B, the polysilicon layer 110 is oxidized forming a protective oxide layer 120. In FIG 1C, a  
15        mask layer 122 is formed to cover the lower portion of the trench, the mask layer 122 comprises, for example, a photoresist material. In FIG 1C, the protective oxide layer 120 not protected by the mask layer 122, is removed to form a protective oxide layer 120'. Then the mask layer 122 is  
20        removed as in FIG. 1E. In FIG 1F, a sidewall nitride layer 124 is formed on the upper portion of the trench by nitridation. The protective oxide layer 120' is then removed as shown in FIG. 1G. In FIG 1H, the protective nitride layer 108 is then removed to form a protective oxide layer  
25        108'. The sidewall nitride layer 124 is removed as shown in FIG. 1I. In FIG. 1J, the lower portion of sidewall oxide layer 106 is removed to form a sidewall oxide layer 106'. In FIG. 1K, the lower portion of the trench is etched to form a bottle-shaped trench by wet etching.

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The above-mentioned bottle-shaped trench fabrication method is complicated, and due to the continuous reduction in semiconductor scaling, this fabrication method is progressively more complicated. Therefore, a simple  
5 fabrication method for forming the bottle-shaped trench is necessary.

### SUMMARY OF THE INVENTION

Accordingly, an object of the invention is to provide a simple method for forming a bottle-shaped trench.

10 To achieve the above object, the invention provides a method for forming a bottle-shaped trench comprising the following steps, providing a substrate with a trench and a pad layer thereon, filling a mask layer in the lower portion of the trench, using plasma nitridation to form a sidewall  
15 nitride layer on the trench sidewall, removing the mask layer, etching the sidewall and bottom of the trench not isn't protected by the sidewall nitride layer, to obtain the bottle-shaped trench.

To achieve the above object and improve the nitride  
20 layer resistance, the invention further provides a method for forming a bottle-shaped trench comprising an added step before plasma nitridation of etching a small portion of pad oxide near the trench to reveal a corner of the substrate. Due to this treatment, the nitride layer has better adhesion  
25 during the sequent etching process.

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### DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, reference is made to a detailed description to be read in conjunction with the accompanying drawings, in which:

5        FIGs. 1A to 1K are cross-sections showing the conventional method for a forming bottle-shaped trench;

FIGs. 2A to 2E are cross-sections showing a method for forming a bottle-shaped trench according to the first embodiment of the present invention;

10       FIGs. 3A to 3F are cross-sections showing a method for forming a bottle-shaped trench according to the second embodiment of the present invention; and

FIG. 4 is a schematic showing the plasma nitridation reactor according to the embodiment of the present  
15 invention.

### REFERENCE NUMERALS IN THE DRAWINGS

4	RF electrode
6	exhaust
8	magnet ring
20	10 reactor
	12 gas inlet
	14 gas injection plate
	16 plasma
	100, 200, 300 substrate
25	102, 202, 302 oxide layer
	104, 204, 304 nitride layer
	106 sidewall oxide layer
	108 protective nitride layer

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110 polysilicon layer  
120 oxidative polysilicon layer  
122, 222, 322 mask layer  
124, 230, 330 sidewall nitride layer  
5 140, 240, 340 bottle-shaped trench  
225, 325 trench

## DETAILED DESCRIPTION OF THE INVENTION

### First Embodiment

FIGS. 2A to 2E are cross-sections showing a method for  
10 forming a bottle-shaped trench according to the first  
embodiment of the present invention.

In FIG. 2A, a substrate 200 is provided. A pad stack  
layer is then formed on the substrate 200 by CVD. The pad  
stack layer is comprised of an oxide layer 202 and a nitride  
15 layer 204. Thickness of the oxide layer 202 is 20~100Å and  
the nitride layer 204 is 1000~3000Å. The pad stack layer is  
used as an etching stop layer for dry etching or chemical  
mechanical polishing (CMP). An opening is then formed in  
the pad stack layer by lithography and dry etching. The dry  
20 etching method comprises reactive ion etching (RIE) and  
plasma etching. Next, a trench 225 is formed by plasma  
etching.

In FIG. 2B, a mask layer 222 is filled to the trench  
225. The mask layer 222 is a photoresist layer. Next, the  
25 mask layer 222 is etched to a level below the substrate  
surface 1000~3000nm by dry etching back.

A key point of the present invention is described in  
the following. In FIG. 2C, a sidewall nitride layer 230 is  
formed on the exposed trench sidewall by plasma nitridation.

The thickness of the sidewall nitride layer 230 is 40~50Å. Therefore fabrication of the sidewall nitride layer protecting the upper portion of the trench in the present invention is achieved in one step and is simpler than the  
5 conventional method.

In FIG 2D, the mask layer 222 is removed by the conventional method.

In FIG 2E, the lower portion of the trench is etched to form a bottle-shaped trench 240 by wet etching. The wet  
10 etching solution is ammonia ( $\text{NH}_4\text{OH} + \text{H}_2\text{O}$ ). The bottle-shaped trench of the present invention is thus obtained.

The key point of the present invention is plasma nitridation step. Nitridation is executed by modified magnetron type nitridation (MMT nitridation) and the reactor  
15 is shown in FIG. 4. In the reactor 10, a plasma 16 is induced by an RF electrode 4. Preferably, the N source gas is selected from the group consisting of  $\text{N}_2$ , NO,  $\text{N}_2\text{O}$ ,  $\text{NH}_3$  and combinations thereof, or the above-mentioned gas mixes with He, Ne, Ar, Kr, or Xe. The N source gas enters the reactor  
20 10 from the gas inlet 12 and gas injection plate 14, passes through the RF electrode 4 the plasma 16 is then induced and deposited on the wafer, then exhausted from the exhaust 6. Preferably, the plasma nitridation temperature is 25~100°C. When the temperature is above 100°C, the photoresist  
25 materials of the mask layer may evaporate. Preferably the pressure range is 30~50Pa and the RF power is 500~1000W.

### Second Embodiment

FIGs. 3A to 3F are cross-sections showing a method for forming a bottle-shaped trench according to the second  
30 embodiment of the present invention.

In FIG. 3A, a substrate 300 is provided. A pad stack layer is then formed on the substrate 300 by CVD. The pad stack layer is comprised of an oxide layer 302 and a nitride layer 304. Thickness of the oxide layer 302 is 20~100Å and the nitride layer 304 is 1000~3000Å. The pad stack layer is used as an etching stop layer for dry etch or chemical mechanism polishing (CMP). An opening is then formed in the pad stack layer by lithography and dry etching. The dry etching method comprises reactive ion etching (RIE) and plasma etching. Next, a trench 325 is formed by plasma etching.

In FIG. 3B, a mask layer 322 is filled into the trench 325. The mask layer 322 is a photoresist layer. Next, the mask layer 322 is etched to a level below the substrate surface 1000~3000nm by dry etching back.

The following step is the key difference between this and the first embodiment. In FIG. 3C, a portion of the pad oxide 302 is etched by diluted HF (DHF) to reveal the substrate corner. The undercut is then filled with nitride layer by subsequent plasma nitridation. The nitride layer with this structure achieves better adhesion during the subsequent etching process.

Another key point of the present invention is described in the following. In FIG. 3D, a sidewall nitride layer 330 is formed on the exposed trench sidewall and the pad oxide undercut by plasma nitridation. The plasma nitridation is executed by modified magnetron type nitridation using the same equipment as the first embodiment. Preferably, the nitridation N source gas is selected from the group consisting of N<sub>2</sub>, NO, N<sub>2</sub>O, NH<sub>3</sub>, and combinations thereof, or

the above-mentioned gas mixed with He, Ne, Ar, Kr, or Xe. Preferably the plasma nitridation temperature is 25~100°C. When the temperature is above 100°C, the PR materials of the mask layer may evaporate. The pressure range is 30~50Pa and  
5 the RF power is 500~1000W preferably. The thickness of the sidewall nitride layer 330 is 40~50Å. Therefore fabrication of the sidewall nitride layer protecting the upper portion of the trench in the present invention is achieved in one step and is simpler than the conventional method.

10 In FIG 3E, the mask layer 322 is removed by the conventional method.

In FIG 3F, the lower portion of the trench is etched to form a bottle-shaped trench 340 by wet etching. The wet etching solution is ammonia ( $\text{NH}_4\text{OH} + \text{H}_2\text{O}$ ). The bottle-  
15 shaped trench of the present invention is thus obtained.

While the invention has been described by way of examples and in terms of the two preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments. To the contrary, it is intended to  
20 cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.